



AEROSOLS & CLIMATE CHANGE



**by Mary Hardin and
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Aerosols are tiny particles suspended in the air. Some occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray.

Human activities, such as the burning of fossil fuels and the alteration of natural surface cover, also generate aerosols. Averaged over the globe, aerosols made by human activities currently account for about 10 percent of the total amount of aerosols in our atmosphere. Most of that 10 percent is concentrated in the Northern Hemisphere, especially downwind of industrial sites, slash-and-burn agricultural regions, and overgrazed grasslands.

Scientists have much to learn about the way aerosols affect regional and global climate. We have yet to accurately quantify the relative impacts on climate of natural aerosols and those of human origin.

Moreover, we do not know in what regions of the planet the amount of atmospheric aerosol is increasing, is diminishing, and is remaining roughly constant. Overall, we are even unsure whether aerosols are warming or cooling our planet.

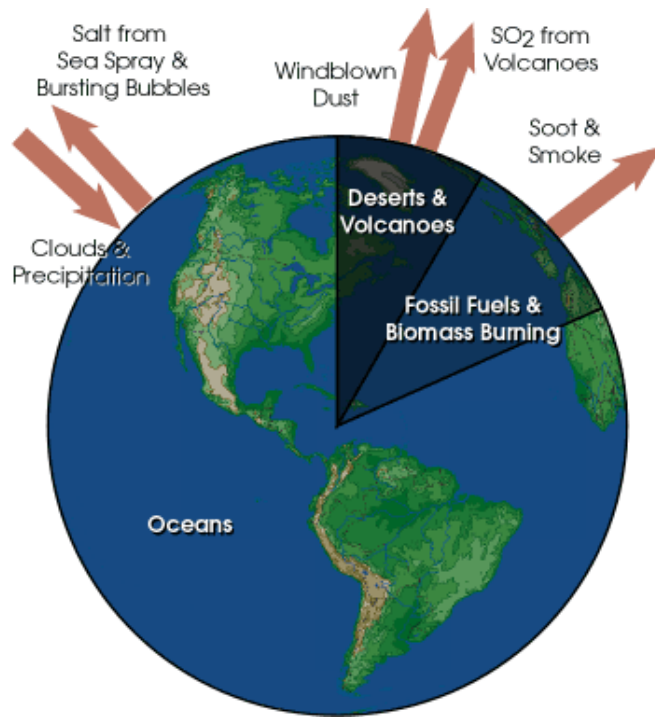


Figure 1. Aerosol particles larger than about 1 micrometer in size are produced by windblown dust and sea salt from sea spray and bursting bubbles. Aerosols smaller than 1 micrometer are mostly formed by condensation processes such as conversion of sulfur dioxide (SO_2) gas (released from volcanic eruptions) to sulfate particles and by formation of soot and smoke during burning processes. After formation, the aerosols are mixed and transported by atmospheric motions and are primarily removed by cloud and precipitation processes.

Why do we care about aerosols?

Aerosols tend to cause cooling of the Earth's surface immediately below them. Because most aerosols reflect sunlight back into space, they have a "direct" cooling effect by reducing the amount of solar radiation that reaches the surface. The magnitude of this cooling effect depends on the size and composition of the aerosol particles, as well as the reflective properties of the underlying surface. It is thought that aerosol cooling may partially offset expected global warming that is attributed to increases in the amount of carbon dioxide from human activity.

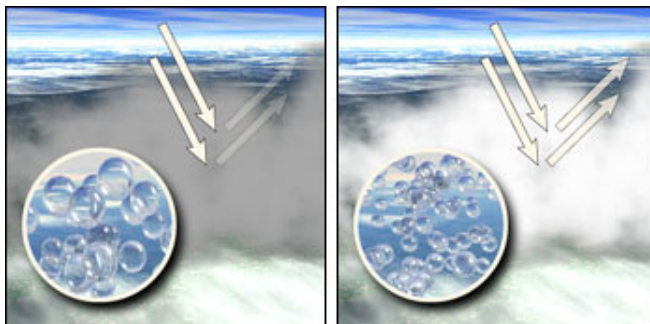


Figure 2a. (left) Clouds with low aerosol concentration and a few large droplets do not scatter light well, and allow much of the Sun's light to pass through and reach the surface.

Figure 2b. (right) The high aerosol concentrations in these clouds provide the nucleation points necessary for the formation of many small liquid water droplets. Up to 90% of visible radiation (light) is reflected back to space by such clouds without reaching Earth's surface.

Aerosols are also believed to have an "indirect" effect on climate by changing properties of clouds. Indeed, if there were no aerosols in the atmosphere, there would be no clouds. It is very difficult to form clouds without small aerosol particles acting as "seeds" to start the formation of cloud droplets. As aerosol concentration increases within a cloud, the water in the cloud gets spread over many more particles, each of which is correspondingly smaller. Smaller particles fall more slowly in the atmosphere and decrease the amount of rainfall. In this way, changing aerosols in the atmosphere can change the frequency of cloud

occurrence, cloud thickness, and rainfall amounts.

If there are more aerosols, scientists expect more cloud drops to form. Since the total amount of condensed water in the cloud is not expected to change much, the average drop must become smaller. This has two consequences -- clouds with smaller drops reflect more sunlight (as explained in Figure 2a & b), and such clouds last longer, because it takes more time for small drops to coalesce into drops that are large enough to fall to the ground. Both effects increase the amount of sunlight that is reflected to space without reaching the surface.

SCIENTIFIC STUDIES OF AEROSOLS

Aerosol particles may be solid or liquid; they range in size from 0.01 microns to several tens of microns. For example, cigarette smoke particles are in the middle of this size range and typical cloud drops are 10 or more microns in diameter. Under normal circumstances, the majority of aerosols form a thin haze in the lower atmosphere (troposphere), where they are washed out of the air by rain within about a week. Aerosols are also found in a part of the atmosphere just above the troposphere (called the "stratosphere"). A severe volcanic eruption, such as Mount Pinatubo in the Philippines in 1991, can put large amounts of aerosol into the stratosphere (Figure 3). Since it does not rain in the stratosphere, these aerosols can remain there for many months, producing beautiful sunsets around the globe, and possibly causing summer temperatures to be cooler than normal. Scientists estimate that Mount Pinatubo injected about 20 million tons of sulfur dioxide into the atmosphere, cooling average global temperatures over the following year by about half a degree.

During the last 30 years, scientists have identified several major aerosol types and they have developed general ideas about the amount of aerosol to be found in different seasons and locations. Still, key details about the amount and properties of aerosols are needed to calculate even their current effect on surface temperatures; so far, it has not been possible to make these measurements on a global scale.

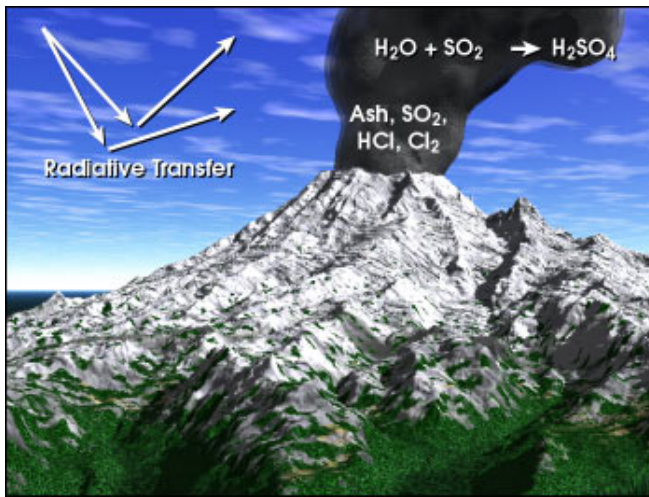


Figure 3. As volcanoes erupt, they blast huge clouds into the atmosphere. These clouds are made up of particles and gases, including sulfur dioxide (SO₂). Millions of tons of sulfur dioxide gas from a major volcanic eruption can reach the stratosphere. There, with the help of water vapor (H₂O), the sulfur dioxide converts to tiny persistent sulfuric acid (H₂SO₄) aerosols. These aerosols reflect energy coming from the sun, thereby preventing the sun's rays from heating Earth's surface. Volcanic eruptions are thought to be responsible for the global cooling that has been observed for a few years after a major eruption. The amount and global extent of the cooling depend on the force of the eruption and, possibly, on its location relative to prevailing wind patterns. (Graphic by Robert Simmon, Goddard DAAC)

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